Aug 2, 2024

# Locus Robotics – High Terminal Temperatures Analysis

## Objective

The aim of this analysis is to determine the root cause of elevated terminal temperatures on our lithium iron phosphate battery model PLR-12V34PL. To achieve this, we created conditions to observe significant temperature increases. Various methods to charge and discharge the batteries and testing chamber set to 45°C to replicate conditions that could potentially lead to these elevated temperatures.

## Hypothesis

We believe that there are various factors contributing to elevated terminal temperatures: the connection method to the terminals for charging/discharging and the wire gauge of the charging/discharging components as well as ambient temperature. While we believe that the connection method has a greater impact,  wire gauge should also be considered.

## Materials and Methods

### Materials

- **Battery Model:** PLR-12V34PL, two battery samples were used.
- **Testing Chamber:** Capable of maintaining an ambient temperature of 45°C +/- 3
- **Charging Equipment:**
    - Alligator clips with 12-gauge wire
    - Charge leads with 8-gauge wire and screw on terminals
- **Discharging Equipment:**
    - Alligator Clips with 8-gauge wire
    - Charge leads with 10-gauge wire (additional test) with screw on terminals
- **Measurement Instruments:** Thermistor probe for monitoring terminal temperature

### Methods

1. **Setup:** The batteries were placed in the testing chamber set to maintain a constant ambient temperature of 45°C. Batteries were allowed to soak at 45°C for 3-4 hours prior to test commencing.
2. **Charging and Discharging Tests:**
    - **Current:** Charging and discharging were performed at a current of 30A
    - **Method 1:** Charging and discharging using alligator clips with 12-gauge wire

- **Method 2:** Charging and discharging using charge leads screwed into the terminals with 8-gauge wire
- **Method 3:** Discharging using charge leads screwed into the terminals with 10-gauge wire (additional test)

3. **Data Collection:** Terminal temperature data were recorded using a thermistor probe attached to the anode of the battery.

# Results

Seven tests were conducted, and temperature data was recorded for each. An example of the data collected is provided below. The complete dataset can be found in the full charge and discharge Excel file. Examples of the discharging and charging graphs illustrating the results are shown below.

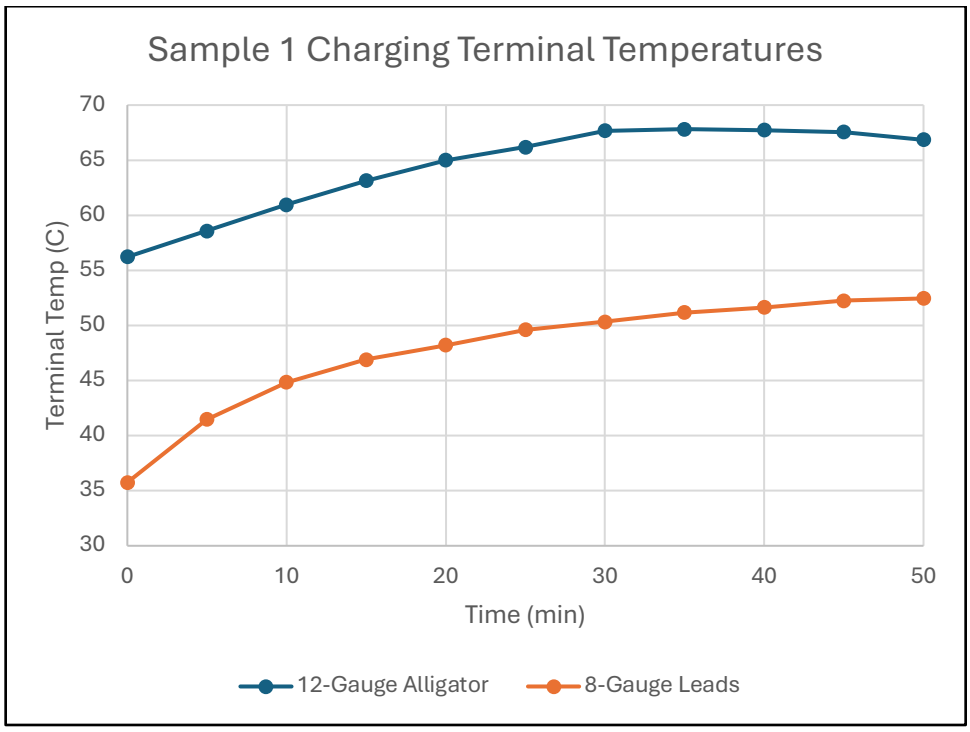
Test: Sample 2 Discharge Test 2

| Time (min) | Ambient Chamber Temp (°C) | Terminal Temp (°C) |
|---|---|---|
| 0 | 44 | 45.15 |
| 5 | 45 | 48.73 |
| 10 | 46 | 51.09 |
| 15 | 47 | 52.69 |
| 20 | 48 | 54 |
| 25 | 48 | 54.95 |
| 30 | 47 | 53.47 |
| 35 | 46 | 51.09 |
| 40 | 45 | 49.60 |
| 45 | 45 | 48.5 |
| 50 | 46 | 48.08 |

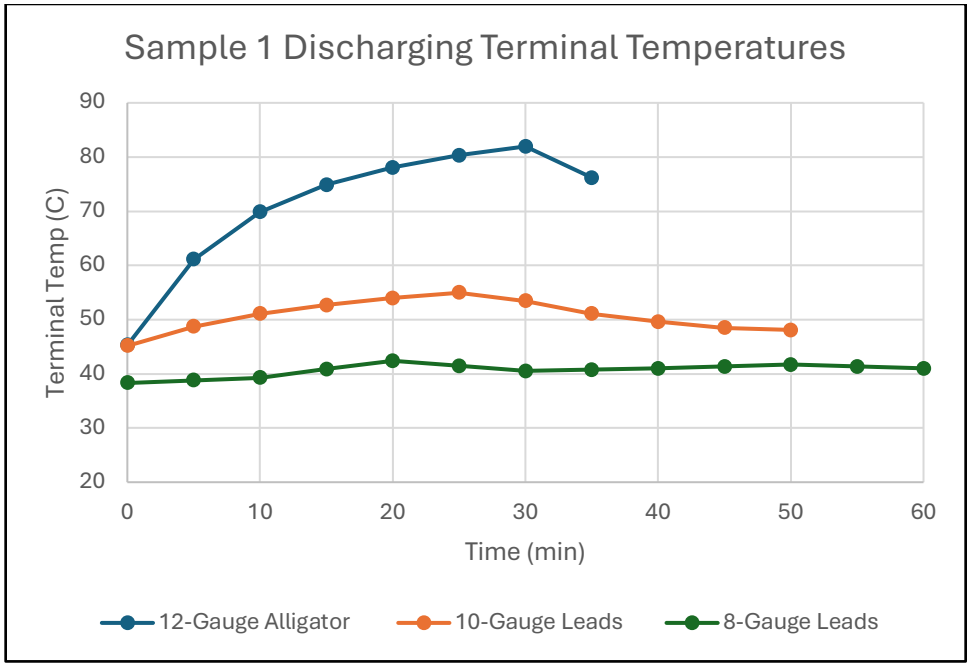
| Average Chamber Temp: 46.09°C |
|---|

# Graphs

## Sample 1 Charging Test Terminal Temperatures




## Sample 1 Discharging Test Terminal Temperatures



# Analysis

## Temperature Trends

- **Charging with Alligator Clips:**
  - Both samples showed a consistent increase in terminal temperature over time
  - Maximum terminal temperatures were significantly higher compared to the use of screwed leads
- **Charging with Screwed Leads:**
  - The terminal temperature increased more gradually and remained significantly lower
- **Discharging with Alligator Clips:**
  - Terminal temperatures showed a rapid increase initially and then stabilized at higher levels
- **Discharging with Screwed Leads:**
  - Terminal temperatures remained relatively stable and much lower compared to alligator clips

## Hypothesis Validation

Our hypothesis was that the connection method, wire gauge and ambient temperature played a part in causing terminal temperature to reach critical point of the epoxy which is 80°C. The data validated these assumptions.

1. **Charging Tests:**
   - Tests with alligator clips, regardless of wire gauge, showed significantly higher terminal temperatures compared to the screwed leads
2. **Discharging Tests:**
   - Similar trends were observed during discharging, with alligator clips resulting in higher terminal temperatures compared to the more stable and secure screwed leads
3. **Additional Test with 10-Gauge Wire:**
   - The terminal temperatures observed with 10-gauge wire were higher than those with 8-gauge wire but lower than those with alligator clips, confirming that wire gauge also impacts terminal temperatures but significantly less compared to the connection method.

# Conclusion:

The results indicate that the use of alligator clips (which simulates a poor connection point) with thinner wires (12-gauge) leads to higher terminal temperatures during both charging and discharging cycles. This is likely due to increased resistance and poor electrical contact associated with alligator clips. In contrast, screwed leads with thicker

wires (8-gauge and-10 gauge) provide a more stable and efficient electrical connection, resulting in lower terminal temperatures. The additional test with 10-gauge wire showed intermediate temperatures between the 8-gauge wire and the alligator clips, confirming that both the connection method and wire gauge are critical factors in thermal performance.

## Suggestions

To avoid high terminal temperatures, the following recommendations are suggested:

1. Ensure Robust Connections Using Screwed-On Charge Leads. Possibly securing the screw by using a lock type washer or Loctite to ensure that the screwed on terminal provides a low resistance connection. Repeat temperature variations hot to cold or cold to hot could cause loosening of the screw as the srew and battery terminal are of two different materials.
2. Suggest using a minimum 8AWG wire if 30A charging is to be utilized.

**Note:** These suggestions are based on tests conducted at an ambient temperature of 45°C.